Ninth graders' learning differences in a healthful-living curriculum

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Abstract:

Physical education and health education are relevant avenues for adolescents to learn knowledge and behavior related to energy-balanced living. Grounded in the *framework theory of conceptual change*, this study examined ninth graders' energy balance knowledge (i.e., concepts, principles, and strategies underlying the scientific mechanism and the outcome of energy balanced/imbalanced living) and physical activity in a healthful-living curriculum (i.e. combination of physical education and health). The students ($N = 195$) were measured using concept mapping, accelerometers, and three-day physical activity recall. It was found that the students differed in energy balance knowledge where most (83%) lacked a higher-order relational understanding. Physical activity in physical education class or after school did not significantly differ by students' mental model levels concerning energy balance knowledge. The findings suggest that an ecological learning context with moderate physical activity should be provided to help students make sense of energy balance knowledge through lived experiences.

Keywords: Conceptual change | Energy balance knowledge | Physical activity

Article:

1. Introduction

The root cause for obesity is the prolonged state of positive energy balance (EB) that is frequently observed in many modern societies (Dunford, 2010, Katz, 2011). Research shows that children and adolescents become steadily less active as they grow older and people in developed countries consume considerably more energy than the older generations (Katz, 2011, Nader et al., 2008). The concepts for developing and sustaining an energy-balanced lifestyle appear to be a vital conceptual base for adolescents to construct knowledge and behaviors needed to maintain a healthy body weight (Jansen, Mackenbach, Zwanenburg, & Brug, 2010). The balance or imbalance between energy intake and energy expenditure is determined in large part by the amount of physical activity (PA) one participates in and the diet behaviors one engages in when consuming food. Thus, concepts about physical activity and food consumption should be a core knowledge to learn. An array of school-based intervention studies support that combining PA and diet is an effective strategy for fostering behaviors leading to energy-balanced living (Katz, O'Connell, Njike, Yeh, & Nawaz, 2008). Of all, teaching adolescents EB knowledge in schools seems a viable strategy (Chen & Chen, 2012). In actuality, physical education (PE) and health education have been considered and used as the major delivery system in school curriculum that educates students with knowledge, skills, abilities, and confidence related to PA and EB (Sallis et al., 2012).

Students engage in structured moderate-to-vigorous PA (MVPA) primarily in school PE and are often encouraged to participate in other activities out of school (Ennis, 2010, Fairclough and Stratton, 2005). While PE offers children and adolescents with opportunities to be physically active, it should, as many researchers recommend (e.g., Brusseau et al., 2011, Ennis, 2007), provide opportunities for students to develop a knowledge base necessary for an active and healthful living. EB knowledge refers to concepts, principles, and strategies underlying the scientific mechanism and the outcome of energy balanced or imbalanced living (Chen and Chen, 2012, Dunford, 2010, Katz, 2011). Unlike PE that is taught in both elementary and secondary schools, EB concepts often appear only in high school curricula (Friedman, Stine, & Whalen, 2009). The curricular arrangement enables children/adolescents to potentially connect PA (i.e., what they can do physically) and EB concepts (i.e., why they should do PA), which forms an integrated knowledge base to guide their decisions for an energy-balanced living. Research studying the topic from an educational perspective is scarce. The literature concerning EB knowledge and its practical significance related to PA is lacking. Thus, the purpose of this study was to determine adolescents' conceptions of EB in relation to their PA behavior in and outside of school. In this endeavor, we employed the framework theory of conceptual change (Vosniadou, 1994) as a theoretical guide.

1.1. The framework theory of conceptual change (FTCC)

The FTCC has been used in studying children's conception and conceptual change in learning scientific knowledge and skills (Murphy and Mason, 2006, Vosniadou, 1994). A main idea of the theory is that existing knowledge forms a stable mental model that guides one's belief system and behavior. A mental model is the conceptual representation of knowledge about external phenomena, which is stored and organized in a dynamic and generative way (Vosniadou, 1994). To change one's belief or behavior, one must change his/her mental model.

Learners bring prior knowledge to school in the form of mental models. The mental models transform as learners are exposed to new information (Murphy & Mason, 2006). Cognitive scientists postulate that learning results from a process of creating, modifying, or restructuring mental models (Murphy and Mason, 2006, Vosniadou, 1994). Mental models are conceptualized in three levels: intuitive, synthetic, and scientific. *Intuitive mental model*refers to one's initial mental model (Vosniadou, 1994). It is characterized by premature or erroneous ideas/misconceptions (Alexander, 2006). Intuitive models are formed due to limited scientific knowledge (Alexander, 2006). *Scientific mental model*, in contrast, represents a mature conceptual structure that holds scientifically correct understandings of a phenomenon (Vosniadou, 1994). Between intuitive and scientific mental models is synthetic mental model. *Synthetic mental model* represents the transitional conceptions between the intuitive and the scientific mental models (Vosniadou, 1994). A synthetic model is characterized by partial understanding of a certain scientific knowledge and is the most frequent representation of conceptions during the learning process.

Mental model transformation relies on three progressive processes (Vosniadou, 1994). *Accretion* occurs when new knowledge is acquired to the current knowledge base. *Weak restructuring* reconciles the newly acquired knowledge with the old (Vosniadou, 1994). The reconciliation does not require significant change in the conceptual structure, if the new knowledge does not radically differ the old knowledge. However, when there is a drastic discrepancy between the new and the old, *radical conceptual restructuring* becomes necessary to revise the entire existing knowledge structure or belief system (Vosniadou, 1994).

The FTCC has been used by researchers to study learners' mental models of fitness and PA behavior. In general, findings confirmed the existence of misconceptions about key kinesiology concepts in children and adolescents. For example, middle school students erroneously equated fitness with the appearance of "looking good" and "being thin" rather than being healthy (Placek et al., 2001, p. 316). Similarly, elementary school students possessed limited knowledge about exercising (Brusseau et al., 2011). In a review, Ennis (2007) summarized that students' knowledge about PA may be organized in large part around misconceptions. These findings suggest a strong need for students to learn scientifically correct knowledge, especially when the knowledge has practical implications for health promotion such as obesity prevention.

1.2. Health-related knowledge and PA promotion

Changing lifestyles from sedentary to active may require radical restructuring of mental models (Ennis, 2007). While little research has focused on the direct linkage between EB knowledge and PA behavior, a positive association between health-related knowledge and behavior was supported by relevant evidence. Kenkel (1991) investigated the association between health-related knowledge and behaviors of smoking, drinking, and exercising (male: $n = 14{,}177$; female: $n = 19{,}453$). It was found that the health-related knowledge positively predicted decreased smoking and drinking, and increased exercising time (responsive coefficients range from .16 to .40). Contento, Koch, Lee, and Calabrese-Barton (2010) examined middle school students' behavioral changes in exercising and eating, the two main behaviors associated with EB. With an experimental design (experimental group: $n = 460$; Control: $n = 437$), the researchers found that learning a new 24 lesson curriculum significantly promoted EB related behavior. The experimental group demonstrated superior behaviors such as purposely walking to school, walking for exercise, purposely taking stairs for exercise, and watching less TV. They also consumed considerably fewer sweetened beverages, snacks, and fast food than the control. Nelson, Lytle, and Pasch (2009) found in an adolescent sample that EB knowledge significantly associated with moderate PA and less television-viewing, but not with sweetened beverage consumption or fast food intake.

The above studies demonstrated a positive association between healthful-related knowledge and behaviors. The findings signal a meaningful message that knowing concepts, principles and information about health plays a role in promoting health-related behaviors such as healthy eating and exercise. It is not clear, however, whether adolescents' mental models about EB will guide their PA behaviors.

1.3. Research questions and hypotheses

As EB knowledge is not taught systematically until ninth grade, it becomes imperative to determine whether the newly acquired knowledge essential to healthful living can be integrated into mental models that have been developed and nurtured since elementary and middle school years. Specifically, this study aimed to address: (a) To what extent did ninth grade students construct the scientific mental models about EB knowledge? (b) To what extent did mental models of different levels predict PA in PE classes and after school? It was hypothesized that mental models about EB knowledge would vary among students and that PA level in both PE and after-school settings would be higher among students with higher level of mental models about EB knowledge (i.e., similar to the scientific mental model).

2. Method

2.1. Setting and participants

Two high schools in a southeastern U.S. state were identified as the research site. The two schools shared similar characteristics of large U.S. public high schools (Sable, Plotts, & Mitchell, 2010). Both schools had large enrollment (> 1400 students). Approximately 60% of students were ethnic minorities and 40% of students were eligible for the federal free/reduced lunch program. The original sample of the study included 195 ninth grade students, with majority from ethnic minority background. Race/ethnicity data were not reported here, as the school district's research office did not approve the disclosure of such information. Due to the missing data from 22 students, 173 students (male: $n = 67$; female: $n = 106$) from 12 classes comprised the final sample for the study. Ninth grade was chosen because EB is a formal content of the healthful-living curriculum at this grade level mandated by the state. Further, ninth graders are at an age threshold (~ 15 years old) when youth PA reaches to the nadir point (Nader et al., 2008); hence focused intervention for PA and EB knowledge promotion is crucial. The study was approved by the *Institutional Review Board* and the school district research office. Parental/guardian consent and student assent were obtained prior to data collection.

Both schools had been using a newly developed PE and health education curriculum, the healthful-living curriculum. The curriculum offered PE and health education, which was taught daily at the two schools. Although PE and health content were combined in the curriculum, they were delivered separately. PE lessons were taught in a multi-purpose gymnasium or outdoor playground. The students were exposed to multiple sports/activities; each activity was offered for one to two weeks. During the two months of data collection, the students experienced ultimate Frisbee, basketball, field events (i.e., shot put and discus), and pickle ball. A typical PE lesson started with warm-up routines (e.g., calisthenics, running/walking laps, and flexibility exercises) and then proceeded to playing the main activity/sport (e.g., basketball). The teachers emphasized more on PA participation than on giving instructions about knowledge and skills. Health education, on the other hand, took place in a regular classroom like other academic subjects. Students were expected to study the content in a seated position, watching slides, taking notes, and discussing various topics. *Holt lifetime health* (Friedman et al., 2009) was designated by the state Department of Education as the required textbook for health education and the readings were reinforced by the teachers during the lessons. Key information such as EB knowledge was presented in lectures using Power Point Slides, an overhead projector, or a chalkboard.

Discussions were organized in small and large groups. No physical activities were offered during health education lessons. The healthful-living curriculum was taught by four certified teachers who had taught PE and health for seven to 28 years.

2.2. Variables and measures

2.2.1. EB knowledge

EB knowledge was measured using concept-mapping. A concept map is a graphic tool typically used in cognitive psychology to measure knowledge organization and representation (Novak, 2005, Novak and Cañas, 2008). A concept map is considered as a tangible illustration of one's conceptual structure about a body of knowledge. Concept mapping is the technical procedure to elicit one's conceptual structure. In the procedure, a student is provided with a list of concepts agreed-upon by experts to be representative of the knowledge domain and is asked to organize the concepts in a relational network by drawing lines and creating clusters to demonstrate his/her understanding of the tested knowledge (Novak, 2005, Novak and Cañas, 2008). A concept map drawn by the student can be deemed as a rough estimation of his/her mental model about understanding of the knowledge. In this study, the following 16 core concepts of EB were selected from the state required textbook for concept-mapping (Friedman et al., 2009): *Calories, energy balance, energy intake, energy expenditure, food, beverage, obesity, weight increase, weight loss, fat, PE, physical activity, physical inactivity, metabolism, carbohydrate*, and *protein*. Each of these concepts met three selection criteria: (a) must be related to energy intake, energy expenditure, or weight management, (b) must be highlighted in the textbook using colored definition boxes or other means (e.g., bolded, italic fond, or graphic illustration) as key concepts, and (c) must have been taught via formal instruction in the healthful-living curriculum prior to the study. The concept maps drawn by the students were scored following a previously validated coding scheme (as shown in Table 1) and two master concept maps (Chen & Chen, 2012). The process generated two variables: concept cluster and concept proposition, representing the lower- and higher-levels of EB knowledge (0–3 scale). *Concept cluster*, as a lower-level of knowledge understanding, refers to gathering concepts that assume an intra-class relation; *Concept proposition*, as a higher-level of knowledge understanding, refers to specifying a relation between every two concepts with a labeled explanation. Concept mapping was found generating trustworthy data in measuring knowledge (Novak, 2005, Novak and Cañas, 2008).

2.2.2. In-class PA

The ActiGraph GT3X accelerometers (ActiGraph, Shalimar, FL) were used to measure in-class PA. The accelerometer is a portable instrument that measures and records PA. It is worn on each participant's left hip through a buckled elastic strap. Once the monitor is fastened and attached to the body, it automatically detects and records body movements in all three physical dimensions. PA intensity (i.e., PA counts per minute) was obtained to capture in-class PA level. Previous research confirmed that the instrument demonstrated high validity among adolescents (i.e., correlation with objectively measured oxygen consumption: $r = .89$ with 70%–87% correct classification for various PAs; Hanggi, Phillips, & Rowlands, 2013).

Table 1. The coding scheme and mental model classification matrix.

1.a. The coding scheme for concept cluster and concept propositions		
Variables	**Count**	**Codes**
Correct concept clusters	Blank or 0 correctly clustered concepts	0
	1–4 correctly clustered concepts	1
	5–8 correctly clustered concepts	2
	9 + correctly clustered concepts	3
Correct concept propositions	Blank or 0 correctly connected propositions	0
	1–4 correctly connected propositions	1
	5–8 correctly connected propositions	2
	9 + correctly connected propositions	3

1.b. Mental model classification matrix					
		Concept propositions			
		0	**1**	**2**	**3**
Concept clusters	0	Level-I	Level-I	Level-II	Level-II
	1	Level-I	Level-I	Level-II	Level-II
	2	Level-I	Level-I	Level-II	Level-III
	3	Level-I	Level-II	Level-II	Level-III

2.2.3. After-school PA

The three-day PA recall (3DPAR; McMurray et al., 2004) was employed to measure after-school PA. The instrument allows participants to recall activities occurred between 3:00 and 10:00 pm every 15 min. In each 15-minute time block, the participants were urged to recall and write down the main activity that occupied most of duration. Over a dozen of daily activities including sports, fitness activities, and sedentary behaviors were listed as examples on top of the survey page. The participants were also encouraged to list activities not being illustrated as examples. The 3DPAR was completed on two random week days and one weekend day to capture the participants' PA during the week. Following the *Compendium of Physical Activities* (Ainsworth et al., 2011), the recalled activities of moderate and/or vigorous intensity were coded as MVPA, and the total minutes of MVPA per day (overall, on week days, and on weekend days) were obtained as the variable for analysis. Previous research demonstrated satisfactory test–retest reliability (r = .98) and concurrent validity (r = .77) for the 3DPAR (McMurray et al., 2004).

2.3. Data collection

Data collection was sequenced as follows: (a) EB knowledge, (b) in-class PA, and (c) after-school PA. The researchers established data collection protocols that were closely followed during data collection. First, the procedures for conducting concept mapping were piloted with a non-participating ninth grade class (n = 30) and then practiced before data collection. The data generated from the pilot session ensured that (a) students at this grade level were able to understand the EB concepts, and that (b) students could follow the concept-mapping procedures within the focused 30 min. In the beginning of data collection, the students were given an opportunity to practice concept-mapping to understand and master the procedures. The practice session used concepts irrelevant to EB knowledge but with similar conceptual structure to allow the students to experience the same concept-mapping procedures they would use in the subsequent data collection session. The mapping procedures were: (a) clustering concepts by gathering them in the same open space; (b) drawing lines or arrows for two relevant concepts; (c) adding a label with relational phrases for each line/arrow. At the completion of mapping EB concepts, the students were prompted to revise their concept maps by exhausting concept relations and adding new relevant concepts, if any.

Second, ActiGraph GT3X accelerometers were distributed in PE to the students on three occasions. Prior to the data collection, students wore the accelerometers as practice for one class (approximately 80 min) to familiarize with the instrument, which hence minimized social desirability bias and reactivity effect. The data collected from the practice session were not used for analysis. Next, the students in each of the 12 classes wore the accelerometer in two randomly selected 80 min PE lessons. The two PE lessons were non-consecutive to control for the difference in PE content natures across classes. Thus, PA data were representative of 24 80 min long PE lessons.

Third, after-school PA was recalled on two weekdays and one weekend day that were most adjacent to the time of recall. On the day prior to each recall, the students were instructed to pay attention to types and durations of the activities that they would do between 3 and 10 pm. On the day of recall, pencils and 3DPAR surveys were distributed in class and the students were prompted to follow recall procedures and report activities as accurately as possible.

2.4. Data reduction

The scientific accuracy of concept clusters and concept propositions was judged by using previously validated scoring rubrics and the two master concept maps (Chen & Chen, 2012). One researcher independently scored all the concept maps to maintain scoring consistency. A randomly selected 25% of concept maps were scored twice to assess intra-rater reliability. The Pearson correlation analysis revealed high intra-rater reliability ($r = .90$). In addition, to reduce in-class PA data, mean PA counts per minute were calculated for the two non-consecutive measurements. PA intensity was assessed by following Sasaki, John, and Freedson (2010) thresholds (light: count < 1952/min; moderate: 1953–5724/min; high: 5725–9498/min; very high: > 9498/min). Lastly, after-school activity data were converted into MVPA time. Referring to the recent *Compendium of Physical Activities*, each recalled activity was coded into MET values (Ainsworth et al., 2011). Activities with intensity equal to or above three METs were converted into MVPA (United States Department of Health & Human Services, 2008). MVPA minutes were computed for each day, weekend, week days, and all three days for analysis.

2.5. Data analysis

The first purpose of this study was to assess the extent to which ninth grade students have constructed the scientific mental models of EB knowledge. To fulfill this research purpose, levels of mental models were evaluated based on the scientific accuracy of the concept clusters and concept propositions. Table 1 shows the coding scheme (Table 1a) and mental model classification matrix (Table 1b) validated by an expert panel after taking into account the performance scores on concept clusters and concept propositions. Specifically, the Level-I mental models were represented by low or moderate accuracy scores in concept clusters and low accuracy scores in concept propositions. The Level-II mental models were represented by moderate or high accuracy scores in concept clusters and moderate accuracy scores in concept propositions. The Level-III mental models were represented by high accuracy scores in both concept clusters and propositions. Frequency (*f*) and percentage (%) of mental models at each level were then calculated and concept-map examples were discussed. The second purpose of this study was to examine the extent to mental models about EB knowledge of different levels was associated with PA in PE classes and during after-school hours. Analysis of variance (ANOVA) was conducted by entering PA variables (in PE and during after school on week days or weekend days) as dependent variables and mental model as the independent variable. A confidence interval of 95% was set to test the statistical hypotheses (α = .05).

3. Results

3.1. Learning differences in mental models of EB knowledge

The students demonstrated different levels of EB knowledge. Table 2 presents the descriptive results of concept-mapping performance. Nearly half of the students (47.2%) performed well on concept clusters. Nevertheless, more than half (61.3%) performed poorly on concept propositions. Taking into account the accuracy of both concept clusters and concept propositions, there were more than half of the students (54.3%) constructed the Level-I mental model while less than a fifth (16.8%) constructed the Level-III mental model. Seemingly, girls' performance results were more favorable than boys on concept clusters, concept propositions, and mental models, as more girls being classified at levels II and III. However, a Chi-Square test did not identify any statistically significant differences in these variables by gender.

Table 2. The *f* (%) of low, medium and high levels of performance in concept clusters, concept propositions, and mental models overall and by gender (*N* = 173).

Score	**≤ 1**	**2**	**3**	**Total**
Concept clusters overall	25 (14.5%)	56 (32.4%)	92 (47.2%)	173 (100%)
Boys	15 (22.4%)	21 (31.3%)	31 (46.3%)	67 (100%)
Girls	10 (9.4%)	35 (33.0%)	61 (57.5%)	106 (100%)
Concept propositions overall	106 (61.3%)	38 (22.0%)	29 (16.8%)	173 (100%)
Boys	47 (70.1%)	12 (17.0%)	8 (11.9%)	67 (100%)
Girls	59 (55.7%)	26 (24.5%)	21 (19.8%)	106 (100%)
Mental models overall	94 (54.3%)	50 (28.9%)	29 (16.8%)	173 (100%)
Boys	44 (65.7%)	15 (22.4%)	8 (11.9%)	67 (100%)
Girls	50 (47.2%)	35 (33.0%)	21 (19.8%)	106 (100%)

Assessing the structure of the concept maps in relation to the rubric and the master maps, there seems to be clear boundaries between the three levels of mental models. Fig. 1depicts a concept map example representing the Level-III mental model about EB knowledge. The students of Level-III mental models were able to correctly cluster the majority of the concepts and label the propositional linkages among the concepts. They were aware that energy intake and energy expenditure were two ingredients of EB with each nesting relevant, though not exhaustive, concepts. Fig. 2 shows a Level-I mental model about EB knowledge. Compared to Level-III mental models, the students of Level-I mental models were only able to cluster several concepts. The clustering often showed unclear and incorrect patterns, and/or the concepts were not propositionally linked together with written descriptions. The Level-I model indicates that a student has gained piecemealed knowledge about EB and lacked of a relational understanding about the core EB knowledge. Further, many concept maps were classified as Level-II mental models. Fig. 3 illustrates a Level II mental model about EB knowledge. These students demonstrated some ability to cluster EB concepts but struggled to link the concepts and label the propositions among these concepts. They seemed to have a partial understanding of EB knowledge, and the room for improvement is obvious.

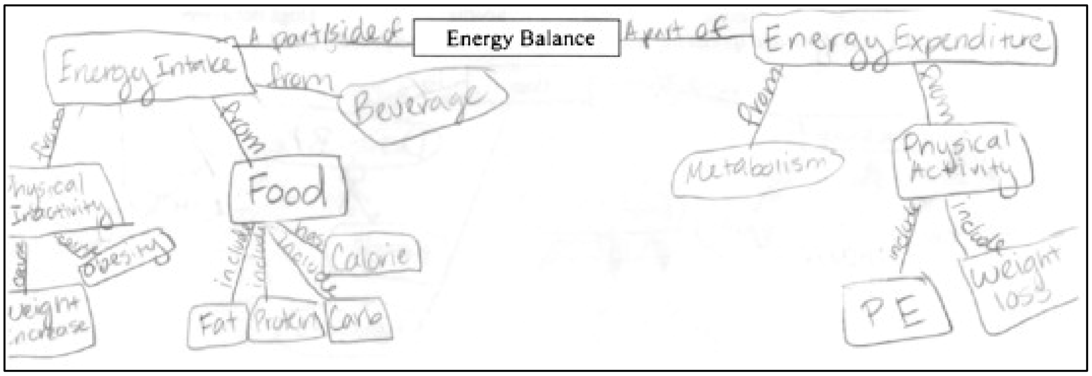

Fig. 1. A concept map example representing Level-III mental model of the EB knowledge.

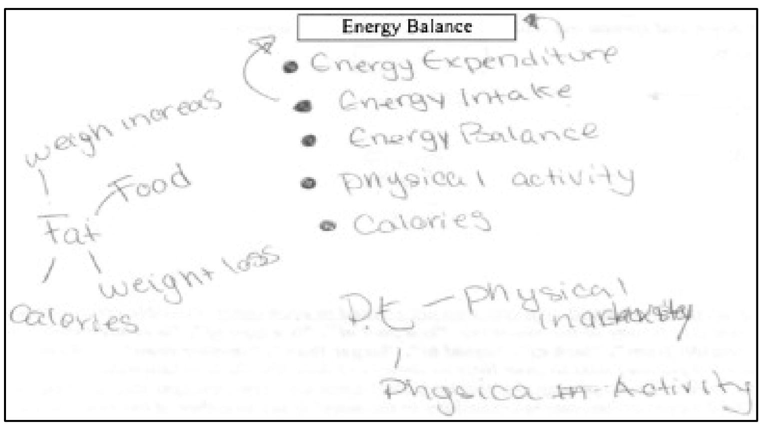

Fig. 2. A concept map example representing Level-I mental model of the EB knowledge.

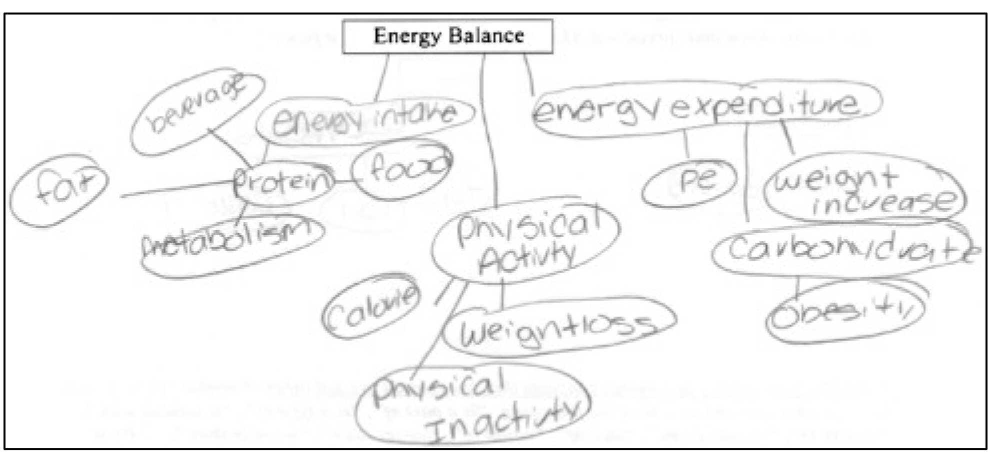

Fig. 3. A concept map example representing Level-II mental model of the EB knowledge.

3.2. PA differences by mental models

The descriptive results of PA behavior in PE classes and after school are reported by students' mental model levels as well as overall in Table 3. Overall, PA level in PE classes was at light to moderate intensity ranging from 870 to 4019 cpm (Sasaki et al., 2010).

Table 3. Mean (standard deviation) of the physical activity variables by level of mental models.

Variables	1 (*n* = 94)	2 (*n* = 50)	3 (*n* = 29)	Overall (*N* = 173)
After-school PA				
Overall	88.16 (59.19)	97.20 (64.42)	76.03 (54.42)	88.74 (60.06)
Weekend days	96.70 (84.24)	102.90 (73.92)	97.76 (90.15)	98.67 (82.00)
Week days	79.63 (66.15)	91.50 (75.82)	54.31 (43.30)	78.82 (66.76)
In-class PA	1879.38 (616.42)	1999.17 (682.10)	1772.58 (534.15)	1896.30 (624.80)

Note. The numbers for after-school PA were in minutes; the numbers of for in-class PA were in activity counts. PA = physical activity.

The students on average participated in sports, fitness, and other PAs for nearly or more than 80 min during after-school hours. After-school PA was higher on weekend days than that on week days. Comparing the PA levels by mental models, the students of Level II mental models seemed to have higher PA levels than others. However, ANOVA results did not identify any statistically significant differences (p > .05). Table 4 shows the bivariate correlations among the variables. The after-school PA variables were positively correlated, so were the EB knowledge variables.

Table 4. The bivariate correlations among mental model and physical activity variables by gender.

Variables	1	2	3	4	5	6	7
1. Mental model	1	.47**	.95**	− .03	.03	− .09	.06
2. Concept clusters	.43**	1	.36**	− .03	.04	− .11	.01
3. Concept propositions	.94**	.33**	1	− .02	.02	− .08	.08
4. After-school PA overall	− .02	.13	.00	1	.86**	.71**	.08
5. After-school PA weekend days	.01	.16	− .01	.88**	1	.24**	.04
6. After-school PA week days	− .04	.04	.02	.80**	.42**	1	.10
7. In-class PA	.09	.18	.17	.18	.11	.20	1

Note. The coefficients above the diagonal are correlations for girls (*n* = 106), and coefficients below the diagonal are correlations for boys (*n* = 67). PA = physical activity.
*p < .05, **p < .01

4. Discussion

This study examined ninth graders' mental models about EB knowledge and their association with PA levels in PE classes and during after-school hours. The results demonstrated that the students held different levels of mental models about EB knowledge and that the mental models were not associated with PA behaviors. These findings indicate that there is a strong need to promote students' EB knowledge and that school reforms are warranted to address the decontextualized learning of the knowledge.

4.1. Synthetic mental models about EB knowledge and learning difference

Although this study classified students' mental models about EB knowledge into three different hierarchies, these mental models should be deemed as synthetic mental models or, in other words, partial understandings (Vosniadou, 1994). The higher hierarchies (Level II and Level III) of the mental models are more approximate to the scientific mental models than the lower hierarchies. In this study, concept cluster and concept proposition were quantified to represent the lower- and higher-levels of knowledge understandings, respectively. The findings revealed that more students performed better on concept clusters (47.2% at Level III vs. 14.5% at Level I) than on concept propositions (16.8% at Level III vs. 61.3% at Level I). Consequently, the overall score of the mental models about EB knowledge was mainly represented by the high score on concept clusters but low score on concept propositions. The results suggest that most of the students have constructed EB knowledge as isolated clusters of concepts rather than as concepts with interlocking relations, a cognitive readiness level for guiding behavior changes. In theory, a higher-order relational understanding comprises a rather complex knowledge structure as opposed to the piecemealed, superficial comprehension (Ennis, 2007). Concept proposition, in this regard, is an indicator of the higher-order relational understanding compared to concept cluster (Novak, 2005, Novak and Cañas, 2008). In this study, the majority of the students failed to construct the correct concept propositions, or the higher-order relational understanding about EB knowledge. The finding indicates the need for educators to foster students' relational knowledge about energy-balanced living.

With constant exposure to the learning content in diverse but relevant contexts, it is expected that students would learn by gradually transforming their mental models to the more scientific mental models (Vosniadou, 1994). While longitudinal evidence is needed to support this argument, the snap-shot data from this study revealed that the ninth graders' mental models of EB knowledge were positioned at different developmental stages. Of all the mental models, the Level-I mental model was held by more than half of the students, which demand great further instructional attentions and efforts from educators. It indicates that despite the hours of formal instruction invested in teaching and learning the EB knowledge in the targeted healthful-living curriculum, little knowledge, especially the higher-order knowledge, was retained in these students' conceptual structures. This finding is consistent with previous evidence that many students in both elementary and secondary schools hold naïve or misconceptions about healthful-living knowledge (Brusseau et al., 2011, Ennis, 2007). We contend that teaching students by merely exposing them to isolated concepts or facts is inadequate to facilitate higher-order learning.

The distribution of three levels of mental models about EB knowledge demonstrated the individual differences in this knowledge. The students with the Level-II mental models of EB knowledge seemed to be cognizant of the EB concepts but only understood the basic relations among these concepts. As ninth grade is the last year for mandatory PE and health education in many U.S. public schools, it is important to design and implement effective strategies to advance students' synthetic mental models about EB knowledge, especially those at Level-I or Level-II, towards scientific mental models (Vosniadou, 1994). Needless to say, conceptual change is never an easy process and scientific mental models are difficult to achieve (Alexander, 2006, Ennis, 2007, Vosniadou, 1994). Shown in our study, even achieving a Level-III mental model (i.e., more proxy to the scientific mental model than Level I and II models) would be challenging and require deliberate instructional effort. In a practical sense, curriculum and instruction should go beyond simply conveying the factual knowledge to students. Instead, instructional practices need to target the relational understanding of the knowledge by urging students to recognize the implications of the knowledge for students' lived experiences or behaviors. It appears instrumental to nurture students' ability to not only know about the facts of energy-balanced living but also identify the propositional linkages among these concepts.

4.2. PA and the decontextualized knowledge learning

Another finding of this study is that the students' PA behavior in class as well as after school did not differ by their mental models of EB knowledge. The disconnection between EB knowledge and PA may lie in the fact that EB knowledge was taught in a decontextualized learning context. As articulated in research literature, learning relies on the systemic, dynamic, and interactive relations between the learner and the content in an ecological context (Alexander et al., 2009). The role of a coherent educational context is extremely important for the learner to interact with and learn the content (Ennis, 2008). In the targeted healthful-living curriculum, the ninth grade students took PE and health classes separately, although the two were administratively combined in one curriculum. In this learning context, despite the high relevancy of the EB knowledge to behaviors, the knowledge was learned in health classes without participating in any physically engaging tasks. Similarly, the students were offered with little intentional guidance in PE (mainly involved sports, games, fitness activities) to make sense of the health-related knowledge learned in health classes. In a sense, such a learning context is not ecological, coherent, and desirable (Alexander et al., 2009, Ennis, 2008), which might have constrained the students from constructing the knowledge-behavior linkage necessary for making important behavioral decisions in PE and during after school hours.

Voluntary behavior or behavioral change is guided by deeply processed cognition characterized by relational understanding of the concepts and behaviors (von Glasersfeld, 1995). Empirical evidence substantiates that the educational context in which students construct health-related fitness knowledge needs to incorporate moderate intensity of PA to increase content relevance and hence learning achievement (Chen, Chen, Sun, & Zhu, 2013). A transmission model of instruction that passes down information from a teacher to students tends to compromise students' efforts to understand “when, where, or why they might use” the new knowledge (Brophy, 2008, pp. 136). Thus, simply transmitting EB knowledge in a health class might have restricted students from constructing the meanings pertinent to both the knowledge and the behavior. In congruence with the above insights, it is recommended that EB knowledge be learned in a physically active context where students could authentically and deeply understand the knowledge and its healthful-living implications through action.

4.3. Conclusion and implications

In summary, this study provided a snapshot of ninth grade students' mental models about EB knowledge and its association with PA behaviors. The students demonstrated three levels of synthetic mental models about EB knowledge, most of whom at the lower levels. EB knowledge was not found as a guiding force for the students' PA behavior. Mental models of EB knowledge constructed in health classes dissociated with PA participation, either in class or during after-school hours. The findings suggest that EB knowledge should be constructed through students' lived experiences in a context enriched by moderate intensity of relevant PA (Chen et al., 2013, Ennis, 2007). Intentional curricular and instructional efforts are necessary to bridge the gap between students' cognitive and physical learning. PE and health education professional should offer deliberate, meaningful learning experiences to promote students' engagement and higher-order relational learning.

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